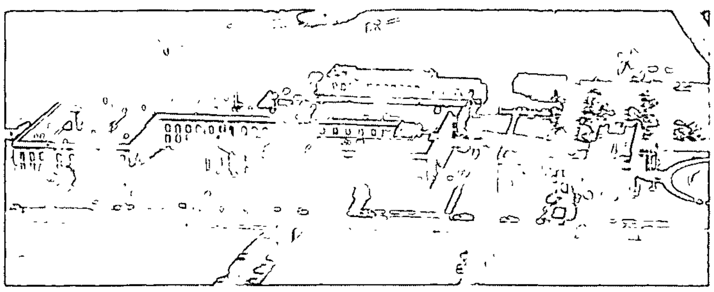

THE INSTITUTE OF PAPER CHEMISTRY, APPLETON, WISCONSIN

A STUDY OF BONDING MECHANISMS OF CORRUGATING MEDIUM

PROPOSAL 2437
AN EXTENSION OF PROJECT 2696-17

To The

FOURDRINIER KRAFT BOARD INSTITUTE, INC.

April 21, 1976

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4/21/76

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I. Introduction

When Project 2696-17 was initiated it appeared that surface receptivity and surface roughness would play an important role in adhesive transfer and hence bonding. However the results obtained on 2696-17 indicated that only surface roughness was involved--the spreading time being too small for absorption to play a significant role. Whether this is the case or not is a point to be determined. It was suggested that this could best be accomplished by a study directed toward determining the fundamentals involved in adhesive application as related to the fluid dynamics associated with pick up of adhesive from an adhesive tray onto the applicator roll, the translation of this film of adhesive to proper proximity with the corrugating medium and the transfer onto the medium.

The Institute of Paper Chemistry was requested to prepare a proposal directed at determining the fundamental parameters involved in these processes and their interrelation with the characteristics of the adhesive (i.e. machine speed and paper properties). We believe it might be best to first develop a firm understanding of the fundamental mechanics controlling film thickness on the applicator roll and then give attention to the transfer of adhesive from the applicator roll to the medium flute tips.

We are aware that CID has had an interest in the conduct of research in this area and it is our understanding that the Forest Products Laboratory has or is conducting research directed along similar lines. In addition to the above we understand that the Langston Company is considering doing development work in this field.

II. Discussion

Reference is made to figure 1 for the following discussion. The applicator roll rotates with angular velocity ω_a in a bath of adhesive. A film adheres to the surface of the applicator roll and is circumferentially translated to the region of the nip formed by the metering roll with an angular velocity ω_m in the same direction as the applicator roll. The relative velocity at the nip is the sum of ($r_a \omega_a + r_m \omega_m$).

The volume of adhesive which is allowed to pass through this metering device is deposited on the surface of the applicator roll and is circumferentially translated to proper proximity with the medium flute tip. At this juncture by a process hypothesized as a combination of wiping and kissing action the adhesive is transferred to the medium. The mechanism of medium reception of this adhesive was the subject of the unsuccessful work conducted on Project 2696-17 which was reported in Progress Report One dated January 15, 1976.

From a technological point of view there are three separate problems to be addressed. First, a purely fluid mechanics effort

LABORATORY ADHESIVE APPLICATOR SYSTEM

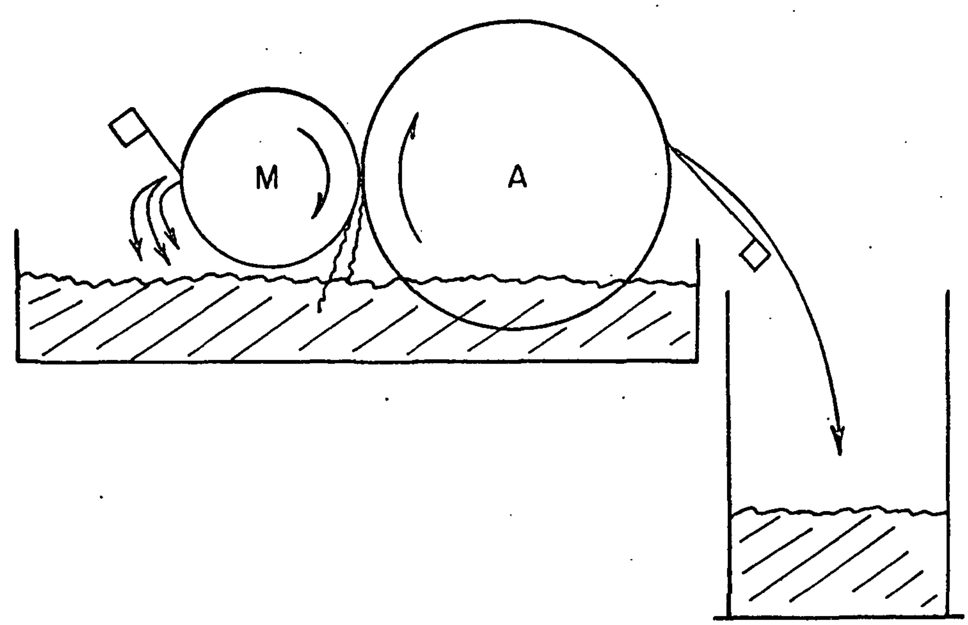

Figure 1

associated with the metering of excess adhesive picked up on the applicator roll. Refer to figure 2. As regards the fluid dynamics associated with the metering a few comments can be made. It is generally believed that the viscosity of the adhesive is a function of shear. If this is in fact the case the fluid flow is non-newtonian and cannot be treated as a mathematically simple newtonian fluid.

There is information in the literature which casts doubt as to whether the viscosity of the adhesive is a function of shear. The literature indicates a linear relationship between film thickness and machine speed. One would not expect a linear relationship between film thickness and corrugator speed if the fluid were non-newtonian.

It is mentioned in the literature that the increase in film thickness is due to a "venturi effect" at the nip. This hypothesis may be questioned. The fluid flow problem in the region of the nip does not resemble a venturi. First, a venturi is a zero shear flow, and the flow at the nip is a strong shear flow! Second, a venturi is a device for measuring flow in a conduit, and the flow at the nip is a metering flow, more akin to a valve than to a flow measuring device. The fluid flow phenomena that exists in the region of the nip is approximately Couette flow.

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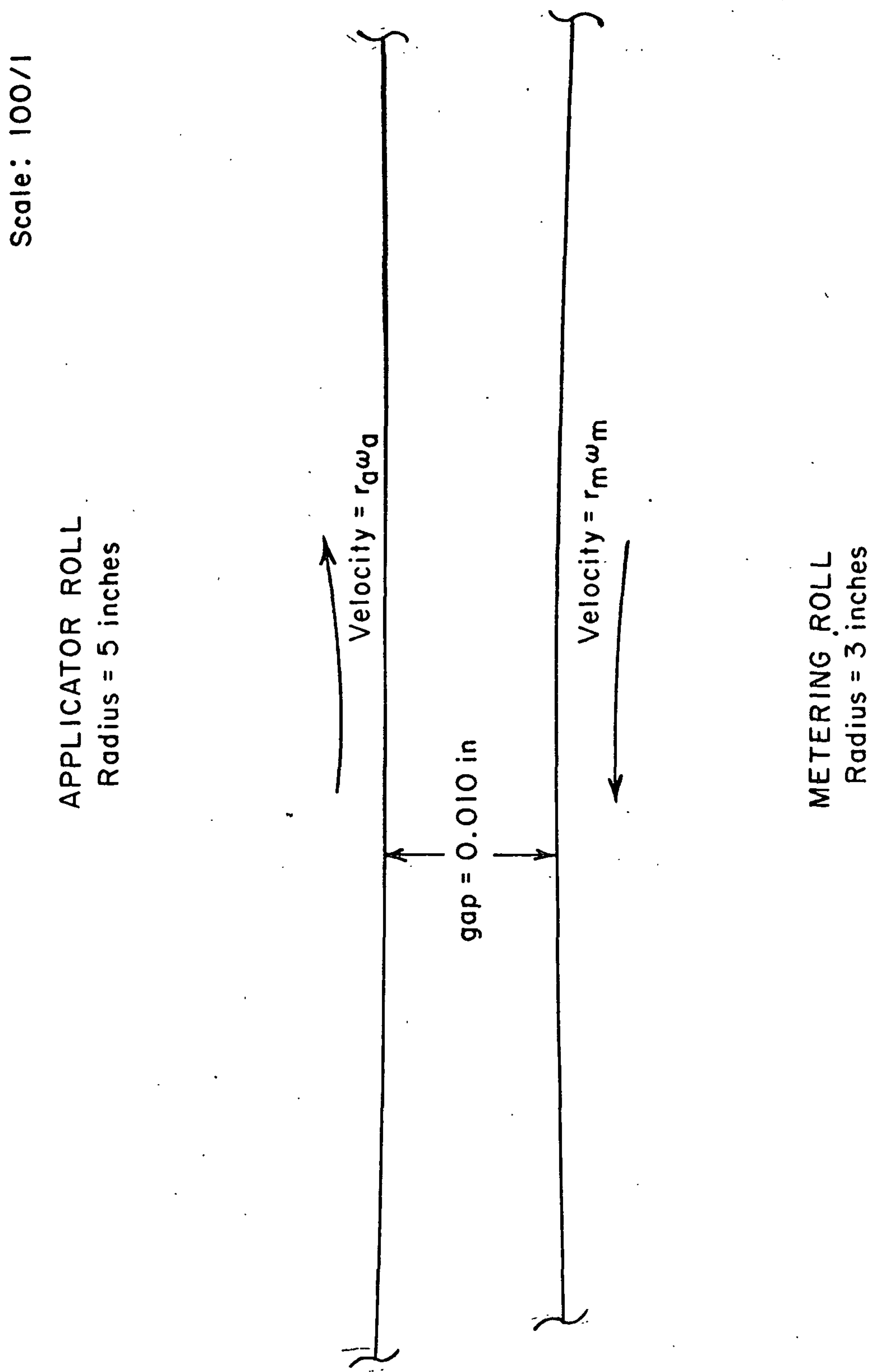

Figure 2

Couette flow is flow between two parallel plates with relative motion between them. There are some differences between the flow of our interest and simple Couette flow:

1) the flow is generally believed to be non-newtonian.
2) there is slight curvature of the boundary, note: r_a is on the order of r_m and both r_a and r_m are 2 to 3 orders of magnitude greater than the metering gap.
3) there is, in addition to shear forces, a body force opposing the flow of adhesive throughout the nip. The force is due to gravity and is the product of the adhesive density and gravitational acceleration.

The second problem is one involving the theory of waves and the instability of the film on the applicator roll, as air, which is entrained by the rotating equipment, flows across the surface of the adhesive on the roll. Refer to figure 3. It is speculated that the wave pattern formed on the applicator roll may be of such a nature as to flood or starve the medium in the cross direction. It is preliminarily speculated that the deleterious effects brought about by waves and wave instability is at worst of secondary importance as compared to the film thickness as a function of machine speed and adhesive properties. The observed waves may be caused not solely as a result of air motion. Mechanical vibrations may be a prime contributor as well.

The third problem is the transfer of adhesive from the applicator roll to the medium. This involves the wiping action and the kissing of the medium flute tip and the applicator roll. Figure 4.

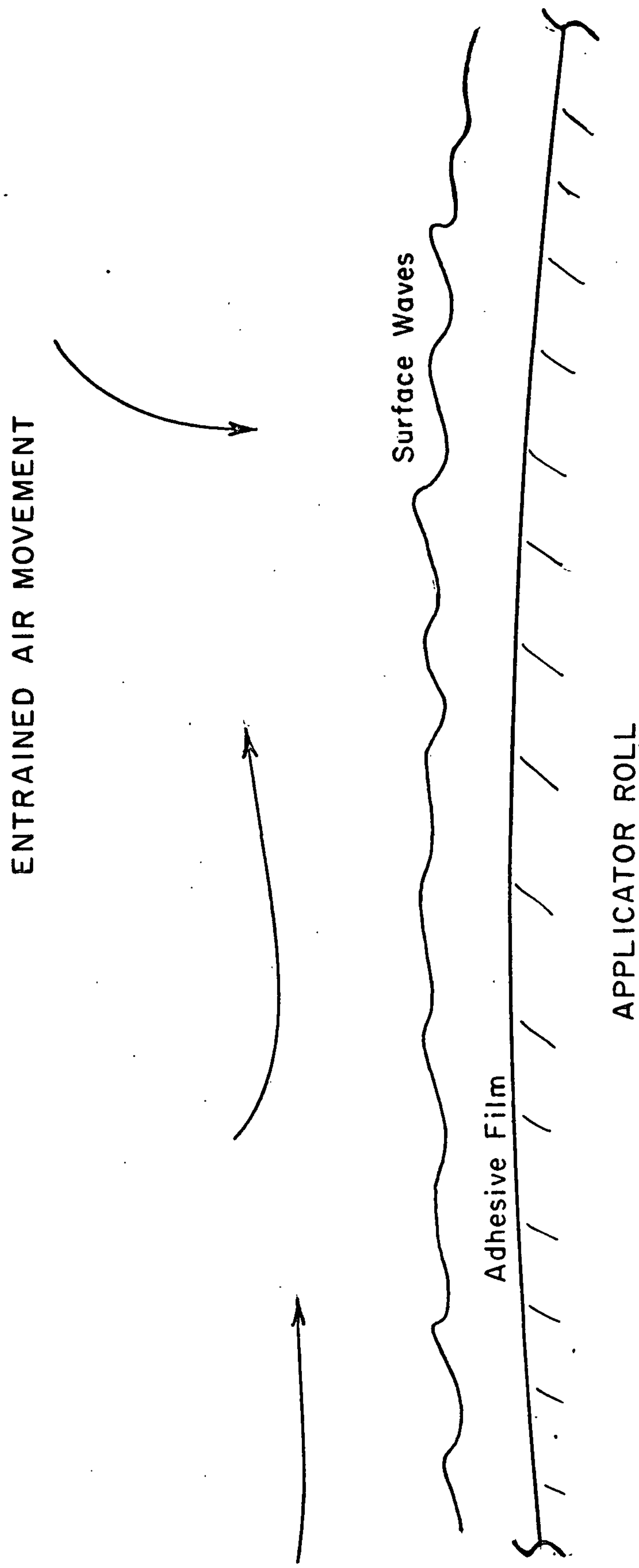
ENTRAINED AIR MOVEMENT
Surface Waves
Adhesive Film
APPLICATOR ROLL

Figure 3

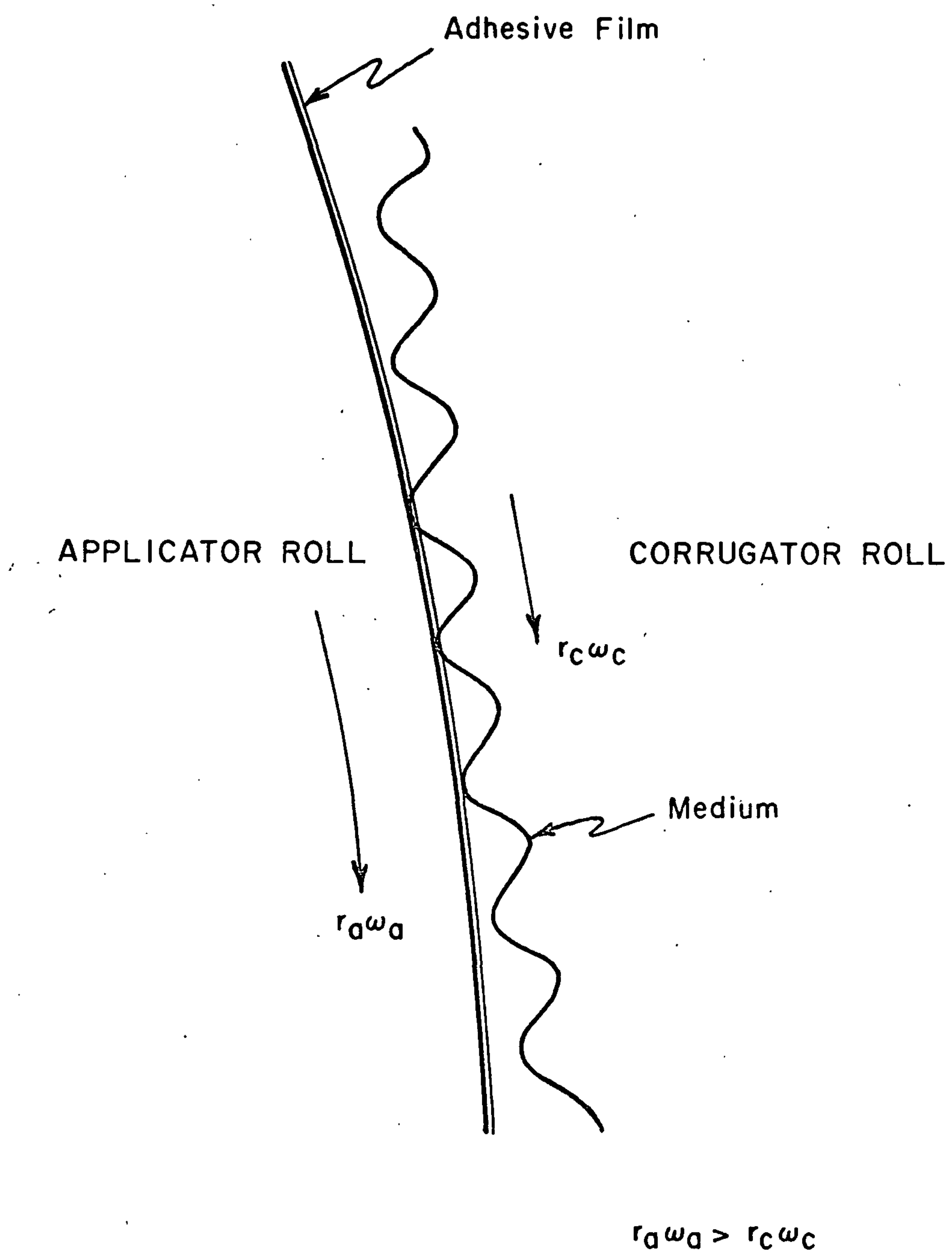
Adhesive Film
APPLICATOR ROLL
CORRUGATOR ROLL
$r_c\omega_c$
Medium
$r_a\omega_a$
$r_a\omega_a > r_c\omega_c$

Figure 4

The problem of adhesive penetration and surface pooling, due to roughness, addressed in the previous effort by IPC on behalf of FKI, remains to be solved. This aspect of the overall bonding potential problem is in most part a surface physics phenonema.

III. Suggested Research Program

It is suggested that this research program be divided into two phases. Phase one would involve the analytical and experimental treatment of the adhesive metering at the applicator metering roll nip and the free surface waves phenomena, phase two would be a study of the transfer of the adhesive from the applicator roll to the medium. This second phase would involve a treatment of the surface physics as addressed in our unsuccessful first effort.

Phase One:

High speed photography would be employed to observe the "to be metered flow" as it enters the nip and the "metered flow" as it exits. Analysis will be conducted to model the flow. From a fluid dynamics perspective this flow appears amenable to analysis. An experimental apparatus similar to that depicted in figure one would be constructed to use in conjunction with the Langston corrugator at the Institute to experimentally verify the analytical model. Once the variables are reduced to a more simple cause and effect relationship we should be in a position to improve adhesive application. It is felt that this order of research (phase one to phase two) is a better approach as the adhesive transfer problem is likely largely influenced by the metering and translation phenomena of phase one. Little can, or should be said of the film uniformity as influenced by wave instability, as it too is likely influenced by upstream metering phenomena.

IV. Time Frame and Budget

It is suggested the first part of phase one be accomplished and funded seperately from the total effort.

The test apparatus constructed for phase one will be utilized only for phase one.

Preliminary cost estimate - phase one/part one

<u>Apparatus</u>		
tank	2,500	
rolls	500	
Collection Devices	500	
Motors and Controls	5,000	
	8,500	8,500
Photography	2,500	11,000
Manning		
Professional	20,000	
Technical	5,000	
	25,000	36,000

This work will be accomplished 12 months after authorization.

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